Atmospheric Modeling and Winds

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Atmospheric Modeling

Atmospheric profiles

Temperature, Pressure and Density

Surface (-4.181 to -1.3 km) to 200 km

Monte-Carlo profile families

Moderate dust load ($\tau \sim 0.3$)

Based on:

- **Ames MGCM results**
- **TES atmospheric retrievals**
- **Viking Lander pressure measurements**
- **Pathfinder surface meteorological measurements**

Limits landing elevation to -1.3 km or lower

Near Surface Atmosphere

Diurnal cycle

- **winds**
- **Near-surface and surface tempreature**

Limits the mission lifetime

Limits the science return

May limit equipment survivability

Wind Modeling for Entry, Descent, and Landing (EDL)

Mesoscale Wind Modeling

Almost no wind data for near-surface equatorial Mars

Mesoscale Models

- **Model meteorological phenomena**
  - **few km to 100 km scale**
  - **some important phenomena unresolved**
- **3-D dynamical atmospheric models**
  - **track pressure, temperature, wind vectors...**
  - **non-hydrostatic equations**
  - **slope illumination and shadowing**
- **Use nested grids for high resolution**
  - **cover area of interest**
  - **necessary context at lower resolution**
- **Computationally very expensive**

Mesoscale Atmosphere Models

Use 2 models to check validity

MRAMS: Scott Rafkin (SJSU)

- **Based on terrestrial RAMS (U Colorado)**
- **Uses Ames MGCM as boundary condition**
- **Kinetic energy conserving grid**
- **$\sim$ 1.5 km highest horizontal grid spacing**
- **Very high resolution Large Eddy Simulation (LES)**

Mars MM5: Anthony Toigo (Cornell) Mark Richardson (Caltech)

- **Based on terrestrial MM5 (U Penn.)**
- **Uses GFDL MGCM as boundary condition**
- **Vorticity conserving grid**
- **$\sim$ 600 m highest horizontal grid spacing**
- **Interactive dust transport**

EDL Wind Analysis

Qualitative Study

Understand site setting

Engineering parameterization

- **Effective (DC) mean wind field**

  Exponential weighting function

- **Scaling MPF shear/turbulence model**

  MPF model reasonable, but not ideal

  Long wavelength by Fourier analysis

  Short wavelength by scaling TKE

Engineering wind profiles

Allows use of EDL Monte-Carlo modeling

Random/selected mesoscale profiles

Add high frequency turbulence

Peer Review

Successful peer review on March 8, 2002

Panel: R. Zurek, J. Barnes, D. Crisp, J. Murphy, R. Pielke, N. Renno

Also attended by project management, scientist and engineers

Review Results:

- **Models are reasonable**
  - **Consistent with atmospheric physics principles**
  - **Consistent with expectations**
    - **season, latitude and topography**
  - **Model intercomparison**
  - **Agreement with Pathfinder meteorological data**
- **Analysis techniques are appropriate**
- **Site to site differences are significant**

Hematite Overview

Little topography

Low background wind

inbetween the tropical jets

Highly convective

small craters enhance convection

Thick boundary layer (≥ 5 km)

Significant updrafts and downdrafts

	MRAMS	Mars MM5
Effective (DC) Wind (m/s)	4 ± 2	4 ± 2
Upward mean wind (m/s)	2.5(1.9)	1.4
Downward mean wind (m/s)	−1.1(−1.5)	−1.7
MPF Scale Factors		
Shear	0.4(0.3)	0.2
Average Turbulence	0.7	
Peak Turbulence	1.2	

- Values in parenthesis are from the LES
- Shear is long wavelength variability.
- Turbulence is short wavelength variability.
- Mean Turbulence is over convective boundary layer

Insert figure 1

Gusev Overview

In southern (eastward) tropical low-level jet

Strong crater rim upwelling and interior subsidence

modified by global circulation

eastward cross crater confined flow

significant wind shear

Thin convective boundary layer

locally enhanced turbulence

Strong nighttime katabatic flow

	MRAMS	Mars MM5
Effective (DC) Wind (m/s)	7 ± 2	3 ± 0.6
Upward mean wind (m/s)	0.4	0.3
Downward mean wind (m/s)	-0.2	-0.3
MPF Scale Factors		
Shear	0.9	0.5
Average Turbulence	1.8	
Peak Turbulence	2.1	

- **Shear is long wavelength variability.**
- **Turbulence is short wavelength variability.**
- **Mean Turbulence is over convective boundary layer**

Insert figure 2

Melas Overview

Canyon driven circulation

- **nighttime down canyon flow**
- **daytime up-canyon flow**
- **calm during flow reversal**

Large up-canyon (westerward) flow

- **enhanced by westward tropical jet**
- **enhanced by thermal tide**
- **enhanced by Tharsis katabatic venting**
- **models disagree on timing**

Extreme up-wall local flow

- **canyon center subsidence**
- **depressed convective boundary layer**
- **sideways thermal "venting"**
- **maintain remnant down-canyon layer**

Insert figures 3 and 4

Melas Statistics

	MRAMS	Mars MM5
Effective (DC) Wind (m/s)	14 ± 5	$1.3^{*} \pm 0.7$
Upward mean wind (m/s)	0.7	0.1
Downward mean wind (m/s)	−0.8	−0.1
MPF Scale Factors		
Shear	0.8	0.5
Average Turbulence	1.6	
Peak Turbulence	2.8	

* **Speeds are signficantly higher 2 hours later (6 ± 3 m/s)**

- **Shear is long wavelength variability.**
- **Turbulence is short wavelength variability.**
- **Mean Turbulence is over convective boundary layer**

Isidis Overview

Mesoscale model runs in progress

Locally flat plain

- Likely to have significant convection
- Possibly modified by tropical jet

Large topographic relief to south

- Relatively close (< 50 km)
- May drive katabatic winds
- Could generate remnant nighttime downslope flow

May be affected by mid-latitude baroclinic storms

Basin has many local dust storms

Best guess is intermediate between Hematite and Gusev